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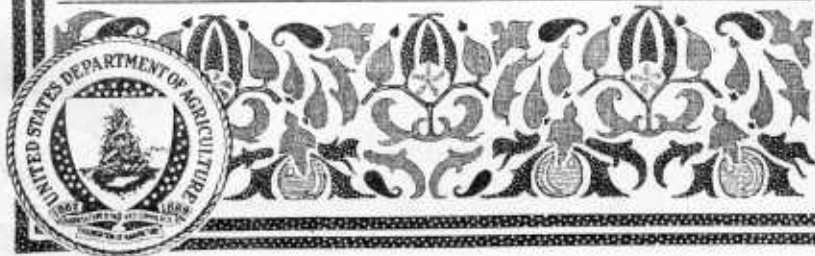
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CITRUS-FRUIT IMPROVEMENT

HOW TO SECURE AND USE
TREE-PERFORMANCE RECORDS



A FEW years ago many California citrus growers were reporting that they were obtaining lower yields of fruit per acre than in the earlier history of their industry. Complaint was also made that an increasing proportion of the fruit of the leading commercial varieties of oranges and lemons was abnormal or "off type" in size, form, color, smoothness of skin, or other important characteristics.

Systematic and continued investigation of this subject in the groves in California since 1909 has disclosed that a considerable proportion of the deterioration observed is traceable to unintentional propagation of undesirable strains of the leading varieties resulting from bud variation.

The results obtained in bud-selection experiments carried on during the last 18 years indicate that by top-working with buds from trees having consistently good records for productiveness and quality the inferior or "drone" trees of such varieties as Washington Navel and Valencia oranges can be made productive and profitable.

This bulletin describes the methods that have been found effective and practicable in locating the desirable and undesirable trees in groves and for transforming the latter when found.

CITRUS-FRUIT IMPROVEMENT: HOW TO SECURE AND USE TREE-PERFORM- ANCE RECORDS

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CONTENTS

| | Page | | Page |
|--|------|---|------|
| Introduction | 1 | Uses of performance records—Con- | |
| Bud variation | 2 | tinued. | |
| Object of performance records | 4 | Individual-tree care | 18 |
| Methods of obtaining the records | 4 | Measure of orchard efficiency | 19 |
| Tree numbers | 4 | Pruning results | 21 |
| Picking and estimate methods | 5 | Progeny tests | 22 |
| Uses of performance records | 15 | Commercial bud-selection practice | 22 |
| Bud-wood selection | 15 | Care of bud wood | 23 |
| Top-working undesirable trees | 16 | Budding | 23 |
| Transplanting bearing trees | 17 | Summary | 24 |

INTRODUCTION

THE ESTABLISHED and proved citrus varieties are the most valuable possession of the citrus industry. The conservation, standardization, and stabilization of these varieties should receive most careful consideration by citrus propagators and growers.

The deterioration or "running out" of these varieties through the unintentional propagation of undesirable strains is responsible for a large proportion of the low yields of inferior fruits in many citrus orchards. The introduction of new varieties to take the place of those which have become unprofitable by careless methods of propagation is usually a matter of experiment. The establishment of new varieties requires long periods of time to prove their value to the grower and to introduce them in the markets.

The use of individual-tree records of production in citrus orchards was originally introduced into California by the writer in 1909. The utility of such records as a factor in the practical work of standardizing the quality and quantity of fruit production in established orchards has been proved experimentally and tested commercially. As a result of these investigations thousands of nursery trees have been propagated and inferior trees in established orchards top-worked with buds selected from productive trees of desirable strains on the basis of their performance records for a series of years. Several thousand of these trees have come into bearing, and so far as can be determined from trees of their age they have without exception reproduced the strain that was propagated.

The nature and extent of bud variability in citrus trees has been studied for several years, and the results of those studies have been published from time to time.

The importance of individual-tree performance records as a basis for measuring the effects of cultural or other tree treatments, in both investigational and commercial work, has become so evident that such records are now regarded by the most efficient and successful California citrus growers as of great value in all orchard work. To determine definitely whether changes in methods of tree culture or care are of value, individual performance records of the trees both before and after the new systems are put into practice should be obtained.

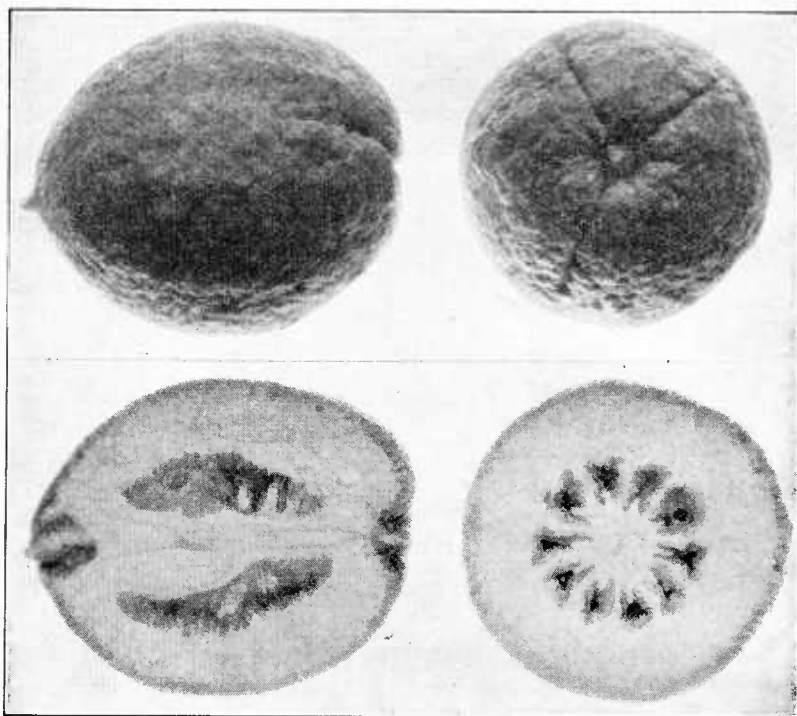


FIG. 1.—Typical dry Washington Navel oranges borne by a limb sport in an otherwise normal fruiting tree; illustrating bud variation in trees of the citrus varieties

The continuing demand from growers for advice regarding a practical method of keeping such records has made necessary the republication of this bulletin.

BUD VARIATION

Although there is no generally accepted theory to account for bud variability in citrus trees, it is, nevertheless, of more or less frequent occurrence in trees of all varieties. It may manifest itself in the habit of growth of the trees or their method of branching, the size, form, texture, or color of the foliage, or the form, color, texture, abundance, or scarcity of the fruits. Occasionally one tree grown

from a single bud will develop several distinct strains of fruit. Frequently a single fruit or a branch bearing several fruits will be found on a tree having characteristics distinct from the fruits of the typical strain borne by the tree as a whole, as illustrated in Figures 1 and 2. Minor variations in fruit characteristics are of very frequent occurrence.

Individual-tree performance records reveal the extent to which trees in commercial plantations differ from one another in their regularity of bearing and in the quality, quantity, and character of the fruit produced.

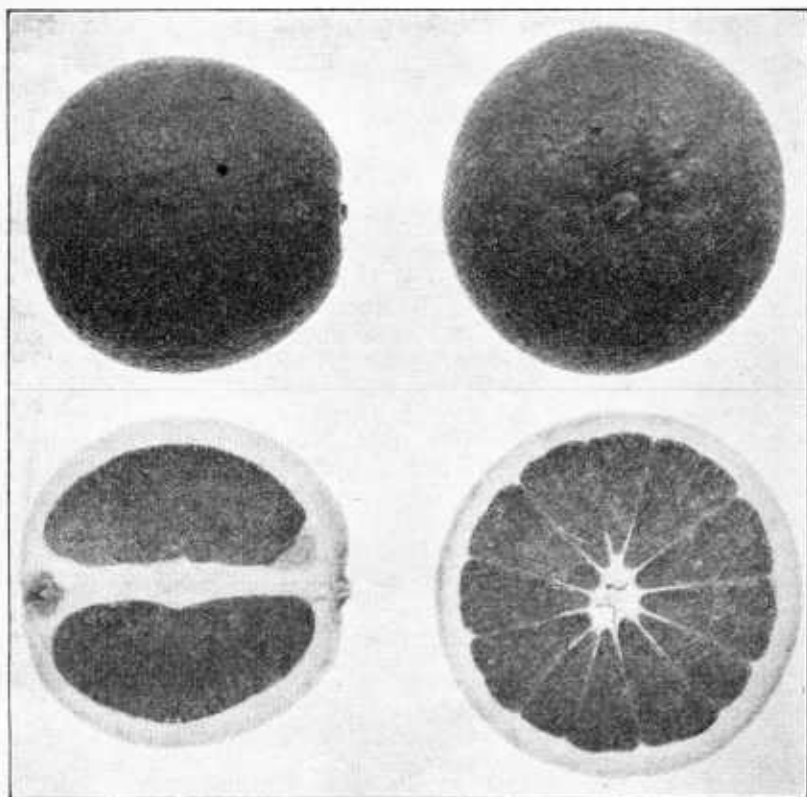


FIG. 2.—Typical Washington Navel oranges borne by normal branches of the tree that also produced the limb sport bearing the dry oranges shown in Figure 1

The nursery propagation of bud variations may be largely avoided through the use of buds selected from individual trees, the performance records of which have shown them to be heavy annual producers of uniform fruit of a desirable strain. Healthy, vigorous-growing citrus trees of inferior strains in established orchards may be successfully top-worked to the best strain and may thus convert into an asset what was formerly a liability of the orchard. Unhealthy citrus trees, those lacking in vegetative vigor or showing unsatisfactory growth characteristics which indicate poor conditions for top-working, can be replanted profitably with nursery or older trees propagated from carefully selected buds.

OBJECT OF PERFORMANCE RECORDS

The object of individual citrus-tree performance records is to obtain reliable information as to the behavior of individual trees in established bearing orchards. This information may be utilized in the elimination of inferior or drone trees by top-working or removing them, in the selection and location of particularly good trees for use as sources of bud wood for propagation, in studying the results of individual-tree treatments, and for other purposes where it is important to know definitely the amount and value of fruit production. Individual-tree performance records enable citrus growers to replace indefinite and oftentimes unreliable opinions as to orchard conditions by exact and definite information, from which safe conclusions may be drawn.

METHODS OF OBTAINING THE RECORDS

TREE NUMBERS

The first step in obtaining individual-tree performance records is to number each tree, so that its record may be kept during successive years without danger of confusion and mistakes in obtaining and recording the performance-record data and other notes.

The numbering system evolved in the investigation of this problem has been adopted by many citrus growers, and provides for each tree a number consisting of three sets of figures. This individual-tree number is made up of the number of the block or division of the orchard, the number of the row in which the tree occurs, and the position of the tree in the row, counting always from some fixed point, such as the irrigation head. For instance, a tree located in block 14, row 18, and the twentieth tree in the row, will have the number 14—18—20, as shown in Figure 3.

The number can usually be painted on the tree trunk or on one of the main limbs. It has been found most convenient to place the component numbers in a vertical column, and they are more easily read when arranged in this form. Pure white-lead paint and an ordinary lettering brush should be used for this work. The numbers should always be placed in the same relative position on all of the trees in an orchard, so that they may be easily found at any time. Where it is not possible to paint the number on the tree, it can be painted or stamped on a wooden or metal tag, which should be attached to the tree where it can be easily seen, and in such a manner as not to interfere with the future growth of the tree. Large, plain figures should be used, so that the number can be read from some distance. One man can usually number 175 or more trees in a day.

This system will prevent the duplication of numbers, no matter how many blocks or trees there are in the orchard; it will locate any particular tree, so that it can be easily found at any time for individual-tree care, for the consideration of its performance record, or for other purposes; it will also promote accuracy and simplicity in recording individual-tree data.

In order to obtain uniformity and accuracy in tree numbers it seems advisable for the members of associations of fruit growers to

have the numbers painted on the trees by a regular crew managed by the association, as is the practice at the present time in picking the crops.

PICKING AND ESTIMATE METHODS

Two methods of obtaining individual-tree performance records are in general use in citrus orchards of the Southwest. The first may be designated by the term "picking method" and the second is usually called the "estimate method." The picking method is carried on by picking each tree separately and weighing the fruits. The estimate record is obtained by estimating the quantity and quality of fruit from systematic observations of each tree before picking, or by an estimate of the percentage of a full crop for each individual tree. In many cases both estimates of quantities and of percentages are recorded.

The picking record is the more accurate and reliable method and is to be recommended wherever practicable. However, it has been found in these studies that it is sometimes impracticable to obtain picking records, and in such instances the

estimate method was introduced as the best possible substitute. The experience in the use of the estimate method during the last 18 years in citrus orchards in the Southwest has proved it to be a valuable system for keeping citrus tree performance records and one which can be safely used in orchards in order to evaluate the performance of the individual trees from the commercial orchard standpoint. In experimental studies, progeny tests, or where exact records are necessary the picking method is preferable. A description of both methods will be given in the following paragraphs, so that the one better adapted for the purposes intended can be used.

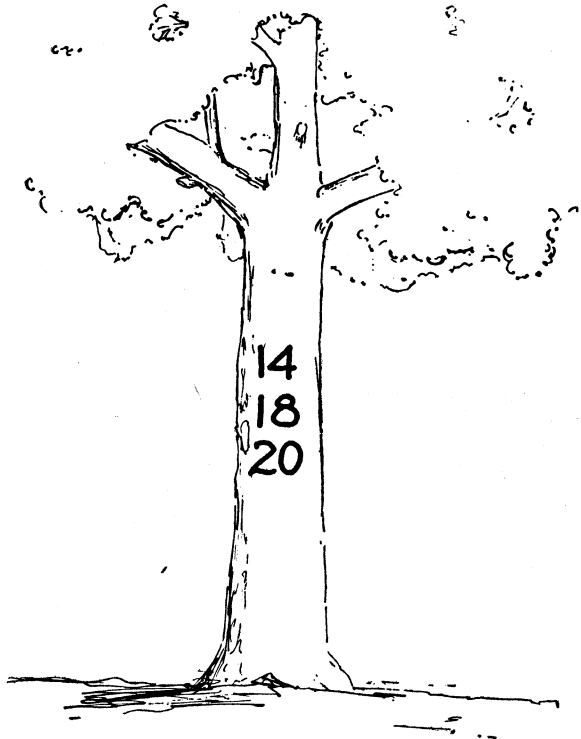


FIG. 3.—Method of numbering trees for keeping individual-tree performance records

PICKING RECORDS

While picking records may not be practicable for recording the performance of all the trees in the commercial orchards, experience has shown that such records are desirable in the case of small plots of trees in these groves where the results of comparative pruning, fertilizing, irrigating, or other tree or soil treatments are to be obtained over a period of years. The simple equipment necessary includes a scale conveniently arranged for weighing the boxes of fruit, field notebooks ruled so as to provide convenient spacing for the yield data and related notes, and a supply of medium-hard lead pencils. Indelible pencils should not be used for this purpose because the figures made by them are likely to become blurred and illegible when moistened. The equipment for this work as used in



FIG. 4.—Equipment used in obtaining individual-tree performance-record data in a number of citrus orchards

several citrus orchards of southern California is illustrated in Figure 4.

PICKING

The organization of the picking crew should be such that one man picks the fruits of an individual tree. The crew can usually be organized so that each picker is assigned to a row of trees. This arrangement frequently induces some friendly rivalry among the pickers and will usually result in more rapid and efficient work than would otherwise be the case. Where tree records are not kept, two or more pickers as a rule work on the same tree, but this practice is not desirable where performance records are to be taken.

The picking boxes should be distributed to the individual trees instead of being assembled in box rows. A little practice will enable

the distributors of the boxes to determine about the numbers of boxes required to hold the crop of each tree.

To avoid carrying fruits to the next tree, the picker should empty his picking sack after finishing each tree. The boxes when filled should be assembled in the shade of the tree from which the fruits were picked in order to protect them from the sun, as shown in Figure 5.

WEIGHING

The crop of fruit of each picking from an orange or grapefruit tree can be expressed in terms showing the number of full and partly filled boxes borne by the tree. In the case of lemon or lime trees, where



FIG. 5.—Boxes of fruits assembled in the shade of the respective trees that produced them. This arrangement protects the fruit and affords a convenient way of obtaining the yield records

frequent pickings are usually made from each tree, the quantity of each picking can be expressed in a manner similar to that for orange and grapefruit trees, or, as is usually done, by determining the actual weight of the fruits and recording the results in terms of pounds.

Many citrus growers who are keeping individual-tree records in their orchards have found that a record of the number of full boxes and the estimated quantity of fruit in the partly filled boxes is sufficiently accurate for their purposes. This method does away with the necessity for any apparatus for weighing the fruits. Where a considerable proportion of the crop of full-bearing trees is picked at one time this method of recording the yield of the individual trees will doubtless prove satisfactory. Where the amount of the pick from

the trees is small, a more accurate record will be obtained by weighing the fruits.

A convenient method for determining the quantity or weight of the fruit in the picking boxes is shown in Figure 4. Figure 6 (*A*) shows a shoulder harness, by means of which an inexpensive spring balance (*B*) is carried. The scale, *a*, provides for weighing a maximum of 50 pounds or a larger amount, depending upon the size of

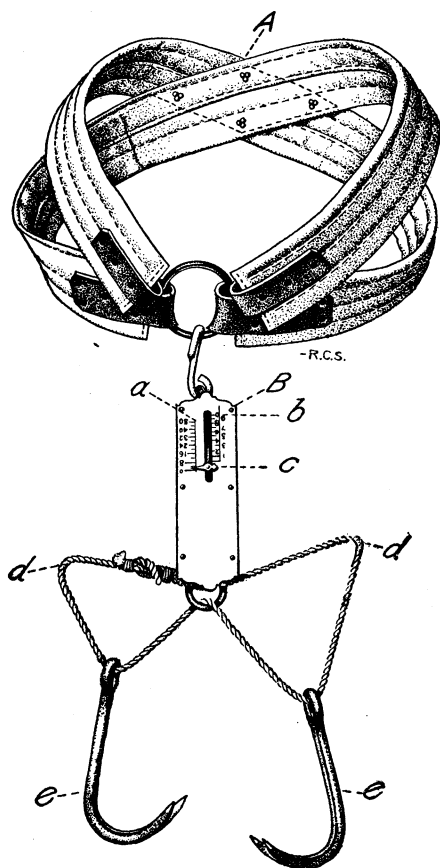


FIG. 6.—Details of the weighing apparatus shown in Figure 4. *A*, Shoulder harness; *B*, spring balance; *a*, scale for weighing a maximum of 50 pounds; *b*, scale calibrated to indicate full box or parts of box in tenths; *c*, pointer; *d*, *d*, ropes; *e*, *e*, steel hooks

the field picking boxes. The opposite scale, *b*, is calibrated by actual trials of empty and full picking boxes, the box tare being marked as 0 and the weight of a full box as 10. The space between these marks is divided into 10 equal parts, numbered from 1 to 10. Such an arrangement provides for determining the amount of the crop in the partly filled box either in terms of pounds or as tenth parts of a box, as desired. The ropes, *d*, are provided with steel hooks, *e*, so that they can be easily attached to the ends of the picking boxes. In using these scales the weigher attaches the hooks to the ends of the box, rises, assuming an upright position, thus lifting the box from the ground, and with it swinging free reads the weight of the fruit.

A little experience with this balance will enable the weigher to obtain accurate records of the amount of fruit in the picking boxes. In the case of a picking crew of 25 to 50 men the weigher will also have time to help inspect and distribute empty picking boxes, load the filled boxes on the orchard wagons, and perform

such other duties as may be necessary to insure the careful handling of the boxes of fruit.

It has been found by experience that in order to obtain reliable individual-tree records it is desirable to have one of the regular picking crew attend to this matter. In one large citrus planting, where individual-tree records have been kept for several years and the picking is done by crews of Mexican laborers, one in each crew keeps the records, inspects the empty picking boxes, and does such

other work as is required in order to promote the careful handling of the fruits. In other cases the foremen of the picking crews are expected to keep the individual-tree records in addition to their other duties. This plan has been found to be less successful than where an extra laborer for each picking crew is provided for this purpose.

In association picking crews, where the crops of the individual members of the association are picked by a general picking crew, the individual-tree records can be obtained in the smaller orchards by the simple expedient of adding one regular laborer to each picking crew. Any intelligent person can quickly learn how to keep the individual-tree records and assist in handling the fruit, so that the expense of the extra man can be justified from this standpoint.

RECORDING THE RESULTS

The date of picking and the quantity and quality of the product of each tree should be recorded so that it can be easily classified and compiled for the intelligent consideration of that individual tree's behavior. The three forms shown herewith are suggested for the use of those who wish to keep such records.¹ The successful use of similar forms in commercial performance-record keeping has proved their practicability. Experience with these forms has shown that a sheet of convenient size is one which provides space for recording the yields of 40 trees. These sheets should have a stiff-back loose-leaf cover or be perforated and bound in covers to facilitate their use in the orchard and to make it possible to assemble the records of any particular block.

The form recommended for keeping orange and grapefruit individual-tree performance-record data for a maximum of three picks in one season from each tree is designated as A.

Form B is recommended for use in keeping individual lemon and lime tree performance-record data, providing for a maximum of 12 picks each season. In this form provision is made for recording the quantity of fruit either in terms of pounds or as the number of full and partly filled boxes.

The commercial grade of the fruits of the individual trees can be recorded by the use of the following or a similar system: *A* may be used to designate the best or first-grade fruits; *B*, inferior, blemished, or second-grade fruits; *C*, cull or third-grade fruits; and *S*, extremely variable fruits as regards shape, size, color, or other characteristics. This system can be extended, if desired to cover other matters of importance in individual-tree care, as, for instance, the letter *X*, to call attention to particularly good trees which may be found suitable for the selection of bud wood for propagation; *D*, to suggest diseased or injured trees; *F*, to mark such trees as may need fumigation; *P*, to show the need of pruning; *T*, to indicate an undesirable tree which should be top-worked or removed; and such other letters or symbols can be employed as may be of value in systematic individual-tree care.

¹ For economy of space, the three forms (A, B, and C) here reproduced as samples are somewhat abridged as to number of trees. In actual use each form is to occupy a full sheet, and a length sufficient to record the yields of 20 or more trees is recommended.

FORM B.—Annual tree records for lemon and lime orchards

| | | |
|-----------|----------------|----------|
| | Season | Variety |
| Block No. | Age of trees | |
| Row No. | Trees per acre | Location |

[illegible]

FORM C.—*Period citrus-tree records*

| | | |
|-----------|----------------|----------|
| Block No. | Age of trees | Variety |
| Row No. | Grove | Location |
| | Trees per acre | |

[illegible]

Experience has proved that in commercial citrus individual-tree performance records only those characteristics of the vegetative growth or fruits which are outstanding should be recorded. In the case of trees where foliage and fruits are apparently normal it is unnecessary and somewhat confusing to record these facts. The successful analysis of these data depends upon their simplicity and freedom from complications, hence all unessential note taking should be avoided.

The data showing the total yield of each tree and the related notes should be transferred to a period citrus-tree record form, such as is shown as Form C. This form provides for bringing together the records of several successive seasons, so that the behavior of each tree during a given period may be studied and compared with that of other trees grown under similar conditions. The number of seasons' records necessary for this purpose varies somewhat according to the conditions, but in all cases an even number of seasons' records is desirable. As a rule, the records of full-bearing trees for two successive normal seasons have been found to be sufficient basis for determining the relative value of individual citrus trees for commercial fruit growing. The records of four successive normal seasons will probably be adequate for use as a basis for the selection of parent trees as sources of bud wood for propagation. In any event, two years' experience will demonstrate to every grower the importance of individual-tree records, from which he can easily draw his own conclusion as to the length of the period for which he should keep these records. So far in the cooperative work of this character few growers have dropped the individual-tree record work after having started it, and some of the records now cover a period of 10 or more years.

ESTIMATE RECORDS

The basis of estimates of the individual-tree yields is the percentage of the crop as compared with a full or 100 per cent crop. For example, the record for a tree which upon inspection appears to have about one-half of a possible full crop would be 50 per cent. Again, a tree bearing only about one-quarter of a full crop would have a record of 25 per cent.

It is oftentimes helpful to record an estimate of the number of boxes of fruit borne by each tree in addition to the percentage figures. From these data the estimates can be checked with the actual production of the orchards. If the trees are very small or have a very light crop for any reason, the number of fruits can be counted and recorded as small fractions of boxes, depending upon the number ordinarily required to fill the field picking box.

SEASON FOR MAKING ESTIMATE RECORDS

The proper season for making estimate tree records is when the fruits are sufficiently mature for their characteristics to be judged and before any picking has been done. In the citrus, owing to the gradual ripening of the fruits, there is usually a period of several weeks during which it is possible to obtain complete estimate records of the quantity and grade of the fruits and notes on any outstanding tree characteristics. In commercial practice these records are usually

finished a few days before the orchard is to be picked or are made by members of the picking crews who work in advance of the pickers.

SYSTEM OF OBTAINING ESTIMATE RECORDS

The estimator walks around each tree, observing the fruit and foliage from all points of view, before recording the notes. It is important that these observations be made systematically and in regular order so as to obtain accurate data. It is helpful actually to pick a few trees in the beginning if possible and compare the estimates with the actual yields. The estimates are best made by trained men who have shown an aptitude for this kind of work and who proceed without any interference or suggestions by others while engaged in it.

RECORDING THE ESTIMATES

A convenient field notebook commonly used for recording the estimate records is about 4 by 7 inches in size and contains about 50 sheets, each of which is ruled to provide space for the data from 20 trees. The size of this book and the ruling of the sheets can be adapted to the conditions in the orchards, such as the number of rows, the number of trees in the rows, or other local circumstances. After their arrangement has been determined it is helpful to have such books printed, to save time in making the estimates and to provide for the uniform recording of the data. The ruling and arrangement of a typical sheet for such books is shown as Form D. Only a few spaces for tree numbers are shown in the illustration. The size of the page and the number of lines can be arranged to suit the individual orchard.

FORM D.—*Typical sheet in notebook, arranged for recording individual citrus-tree estimate data*

Location..... Block.....
Variety..... Orchard..... Row.....

[illegible]

Records by:

Date _____

The books should have a stiff back cover to provide suitable conditions for writing the notes. On the inside of the flexible front cover should be printed rules and directions for making the records. A typical list of instructions for this purpose is shown in the following paragraphs:

USES OF PERFORMANCE RECORDS

BUD-WOOD SELECTION

Citrus bud wood for commercial propagation should be cut only from the best trees of the most valuable strain. These trees should be selected on the basis of their performance records and from intimate knowledge of the individual trees.

The condition of uniformity in size, shape, color, texture, and other characteristics of the fruits borne by a tree is considered a reliable indication of the inherent stability of that particular tree. It has been found experimentally and proved commercially that, if all of the fruits borne by a tree during a season of normal production and more particularly for a period of several years of normal fruiting are consistently alike, the characteristics of the progeny of that tree will probably be uniformly like those of the parent tree. On the other hand, if there is marked variability in the individual fruits or the fruits borne by the different limbs of a tree for a season or for a



FIG. 7.—Typical fruit-bearing bud wood in a selected Eureka lemon tree, showing the kind of growth most desirable to use for budding in the citrus varieties

period of several normal years, the progeny trees are likely to be variable even though buds are taken from the normal branches of the parent tree. In other words, the condition of uniformity in the characteristics of the parent tree tends to be perpetuated in its progeny.

For careful tests in progeny propagations only fruit-bearing bud wood should be used, and every bud stick should have one or more typical fruits attached, if possible, when cut from the select parent trees, as shown in Figure 7. In general commercial propagation, all the young healthy fruit wood produced by the selected trees is

used. Such bud wood has been found to produce trees of satisfactory growth which bear early and regular yields of fruit.

In the past sucker growth has been generally used for propagation and little or no attention has been paid to the number or quality of the fruits borne by the trees from which bud wood has been obtained. In many cases this practice has naturally led to the propagation of inferior strains. The large proportion of trees of undesirable strains found in many citrus orchards was due to this lack of care in the selection of bud wood.

TOP-WORKING UNDESIRABLE TREES

The elimination of trees of undesirable strains from established orchards has been effected by top-working these trees with select

buds from trees of a desirable strain, as illustrated in Figures 8 and 9.

Although trees of some of the inferior strains can be recognized from their habits of growth or other vegetative characteristics, as shown in Figure 10, it is desirable wherever possible to make the final selection of trees to be top-worked on the basis of their performance records and the characteristics of the fruits borne by them.



FIG. 8.—A top-worked unproductive Washington Navel orange tree, showing the arrangement of the budded limbs and the nurse limb (right) which is left for one or two years after the budding operations, so as to protect the inserted buds and to provide the best possible conditions for their growth

The selection of the bud wood for top-working purposes should be based on individual-tree performance records and

an intimate knowledge of tree characteristics obtained by careful observation.

The first top-working on a commercial scale as a result of the bud-selection investigations of the United States Department of Agriculture was done in the summer of 1911. In a 235-acre orchard of 8-year-old Eureka lemon trees, approximately 2,500 trees of inferior strains were top-worked with buds from carefully selected trees in the same orchard, as shown in Figure 11.

Notwithstanding the extremely cold weather of the succeeding two winters, which very seriously injured the growth from these buds, the rebudded trees are at the present time as productive as the other trees in the orchard, and without exception the strain that was propa-

gated has been reproduced, so far as can be determined. Each year since that time several thousand trees in various citrus orchards in California have been budded or top-worked on the same basis, and those that have reached bearing age have reproduced the characteristics of the strain that was propagated.

TRANSPLANTING BEARING TREES

Transplanting selected bearing citrus trees may sometimes be a desirable practice when nursery-grown trees are not available for planting to fill vacant spaces or to provide better tree spacing for cultural operations.

In several instances during the last 10 years in the Southwest large numbers of bearing citrus trees from 6 to 12 years of age have been transplanted from one orchard location to another. In this work individual-tree performance records have been used where possible for the purpose of selecting only the desirable and productive trees for moving. The cost of transplanting the bearing trees has been greater than that of planting nursery trees, but the transplanted ones have produced profitable crops from two to four years earlier than the nursery trees.

In transplanting, performance records for two or more years are desirable, in order to select satisfactory trees and to discard undesirable ones.

The most successful economic system is to use the bare-root method, exercising care to keep the freshly dug root system protected from exposure and thoroughly moist at all times. The trees should be planted without delay after digging and irrigated immediately. Experience has shown that the best season for transplanting is during the late winter and spring months.

One of the most important operations in transplanting is the cutting back of the tree growth in about the same degree of severity as for top-working, this being done a few days before the trees are to be dug. The remaining branches should then be thoroughly covered with whitewash. In digging, care should be used to avoid destroying the small roots, and all cuts should be made with sharp



FIG. 9.—A top-worked Australian strain Washington Navel orange tree two and one-half years after top-working. The original unproductive tree has been changed to a productive one

shears. A typical selected Valencia orange tree 6 years old properly treated for transplanting is shown in Figure 12.

INDIVIDUAL-TREE CARE

In most of the larger citrus orchards of the Southwest one or more employees devote all of their time to the care of individual trees, including the treatment of trees that have been attacked by disease, insects, or rodents, the removal of broken or undesirable limbs, the special care of top-worked or transplanted trees, and other individual-tree treatments. In the smaller orchards this work is usually carried on by trained men hired for this purpose or by

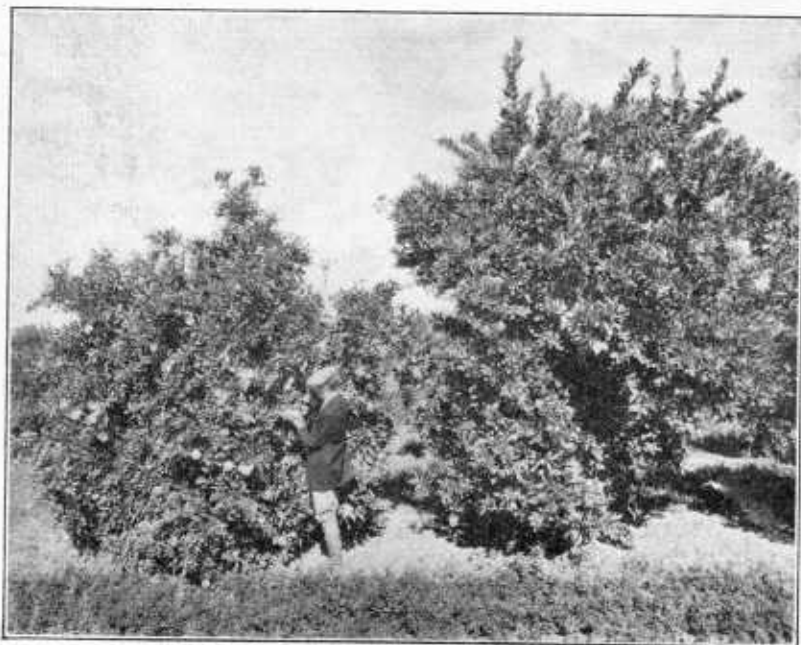


FIG. 10.—A typical rank-growing and unproductive tree of the Australian strain of the Washington Navel orange (right), compared with a normal tree of this variety. The Australian trees of the Washington Navel orange and other vigorous but unproductive trees in all of the established citrus varieties grown in the Southwest have been successfully top-worked and brought into profitable production through the use of bud wood obtained from superior parent trees

the owners of the groves. This systematic attention has been found to be profitable and is receiving more and more attention on the part of the citrus orchardists. In order to carry on this work intelligently and to evaluate the results, individual-tree performance records are invaluable.

Most of the care of individual trees must be continued several years in order to complete the work. With the treated trees scattered throughout the orchard it is obviously very difficult, if not impossible, to locate and treat them intelligently without definite tree records.

Transplanted and top-worked trees require special attention in pruning, insect and disease control, fertilization, irrigation, and other cultural care for a period of three or more years. Diseased

trees oftentimes need annual treatments for several years. Injuries by rodents such as rabbits, rats, mice, squirrels, or gophers are found more or less continuously throughout the life of the orchard. Inarched or bridge-grafted trees need some attention in the removal of adventitious growth or other care for several seasons. The saving in time and labor in this work as well as its increased efficiency has usually more than paid the cost of keeping individual tree-performance records in the orchard as a whole.

MEASURE OF ORCHARD EFFICIENCY

The average annual yields of the individual trees in the orchard for a period of not less than two and preferably four or more con-

secutive years can be used to classify the trees in three groups:

(1) Those that are profitable; (2) those that produce only enough crops to pay for their maintenance; and (3) those that are maintained at a loss by reason of poor crops.

In the development of methods for using the information obtained from performance-record data in these investigations it has been found helpful to chart the average annual tree yields for each commercial orchard block so as to show graphically the distribution of the trees of the different classes. Several methods originated by the writer and his associates or by co-

operating citrus growers in the Southwest for accomplishing this object are in use, and three of them will be described briefly in the following paragraphs.

In all the methods cross-section paper, arranged so that one section is provided for each tree in the orchard block, is used for making the performance-record chart. It is helpful to indicate on this sheet the performance-record period, the location of irrigation flumes, terraces, high or low spots, windbreaks, or other related information.

The first and most widely used method of charting the location and classification of the trees is with figures giving the data of average tree yield, using inks or pencils of different colors to indicate the groups that do not produce enough crop to pay for their upkeep, those



FIG. 11.—A rank-growing and unproductive lemon tree top-worked with buds from a superior parent tree. This and many similar trees in this orchard have come into profitable fruit production about three years after top-working.

that yield only enough fruit to pay for their maintenance, and those that produce profitable crops.

The second method is to show the individual-tree yields on the cross-section sheet by shading or inking in each section in the relative location of the trees the amount or intensity of shading indicating the tree yields, as shown in Figure 13.

A third method is to use symbols to indicate the three classes of trees, based on their average annual yields, such as A for the profitable trees, B for those that are neither profitable nor unprofitable, and C for the unprofitable trees.

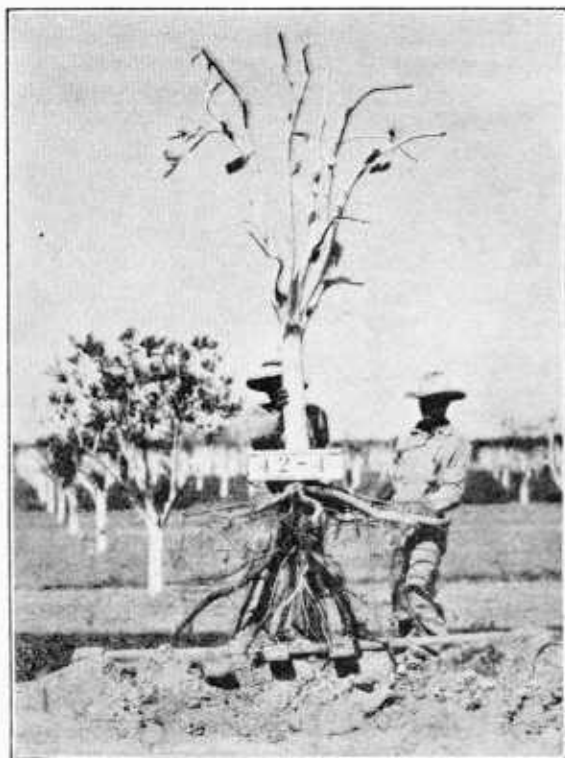


FIG. 12.—A 6-year-old Valencia orange tree which has been selected on the basis of individual-tree performance records as desirable for transplanting and properly pruned, whitewashed, and otherwise treated.

The study of such performance - record charts showing the distribution and location of the different classes of trees has proved to be valuable in determining the causes of unprofitable orchard areas and the efficiency of cultural or other orchard-management practices. For example, in a large Washington Navel orange orchard where this method was first used certain areas were found to be very unproductive and unprofitable. These areas were determined to be those where the topsoil had been removed during the process of grading before the trees were planted. An experimental resur-

facing with fresh soil of a part of several of these spots proved that it was possible to increase the tree yields to profitable production, and this method has since been generally used for improving the soil conditions in such areas.

In another instance the performance-record charts showed a gradual falling off in the tree yields the farther they were removed from a distance of 300 feet from the irrigation flumes or sources of water. Additional flumes were installed at the points indicated as necessary by the charts, with a consequent decided improvement of yields owing to the better distribution of the irrigation water, and this practice has been widely used subsequently in commercial orcharding in the Southwest.

The performance-record charts can be used to study the effect of local soil conditions on tree yields, the results of fertilizer practices, the relation of the lay of the orchard to frost or other temperature injuries, together with many other orchard conditions, and to provide an intelligent basis for correcting undesirable conditions, when possible, and systematically improving cultural practices.

PRUNING RESULTS

The severe pruning of citrus trees in the Southwest has been largely abandoned as a result of the study of the performance records of severely pruned as compared with those of lightly pruned trees.

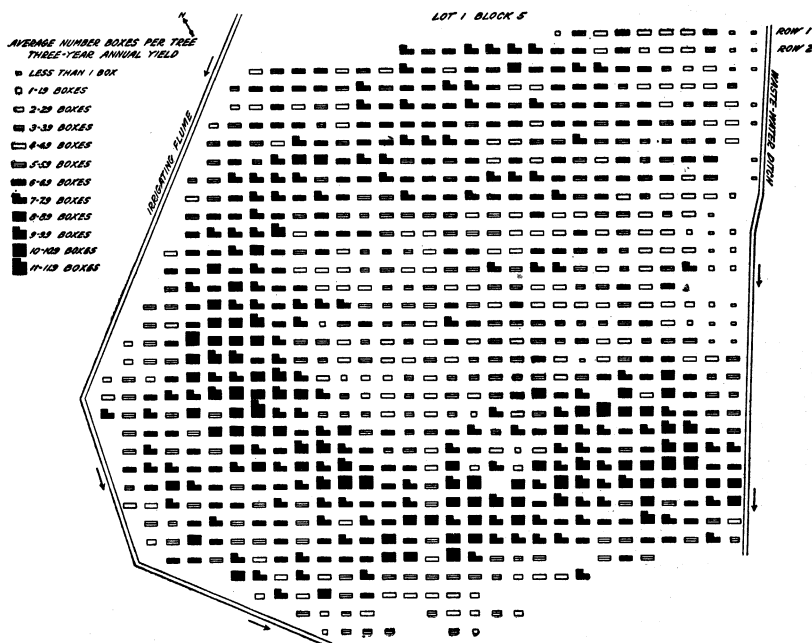


FIG. 13.—Diagram showing graphically the distribution of the citrus trees in an orchard and the average quantity of fruit borne by these trees for a period of years

These records showed that the tree yields were reduced about in proportion to the degree and severity of pruning and without any compensating advantages.

The present practice which has grown out of this experience includes a light pruning consisting of the training of strong framework branches in young trees, the removal of dead, injured, unproductive, or undesirable limbs on bearing trees, and the opening up of dense growth in older trees for the purpose of gradual tree renewal.

In the selection of undesirable or unproductive limbs such limbs should be marked and their location noted in the tree records. After two or more years of observation if they prove to be consistently undesirable and unproductive, they should be cut out, care being taken to make smooth sloping cuts and fresh cuts of more than 1

inch in diameter being covered with grafting wax or other protective material.

In view of the loss from severe pruning in the citrus and the danger of serious loss of crops for several years following injudicious pruning practices, it is important that the results of pruning methods be determined by means of tree-performance records. If it is considered desirable to make a change or to try new methods of pruning, the results of the use of these methods on a small scale should be obtained for a period of years before any radical change or new methods are introduced into commercial practice.

PROGENY TESTS

In order to determine definitely whether or not unusually high-yielding trees are inherently productive, progeny tests of such trees should be carried out. For this purpose buds taken from the selected trees can be inserted in nursery stock or top-worked in bearing trees, not less than four and preferably more progeny trees being used for each test. If the performance records of the progeny trees of a high-yielding parent tree show consistent productiveness, these results may be accepted as proving that the productiveness of the parent tree was due to inherent causes rather than to environmental influences. Abnormally low-yielding trees may be tested in the same manner.

The results of performance-record work with progenies of trees of particular interest can be used as a guide in the further propagation of the parent trees or strains arising from them. In the southwestern citrus orchards most of the bud wood now used in the propagation of the established citrus varieties is obtained from selected trees in superior and uniformly high and desirable yielding progenies.

COMMERCIAL BUD-SELECTION PRACTICE

One of the most important uses of individual citrus-tree performance records is in the selection of trees of proved varieties that have been found to bear consistently high yields of uniformly desirable fruits as sources of bud wood for propagation. In the beginning of this work in California in 1909, individual tree records were kept for a period of years and bud wood was cut from the best yielding trees in the established orchards. Subsequently, it has been possible to obtain as a rule adequate supplies of bud wood from the best trees of the superior progenies of the selected parent trees, based upon period individual-tree performance records.

The obtaining and distributing of commercial bud wood for propagation in California has been carried on since Mar 1, 1917, to date, by the Fruit Growers Supply Co., a cooperative nonprofit organization of about 12,000 citrus growers and a subsidiary of the California Fruit Growers Exchange. From the beginning until December 31, 1927, more than 3,933,000 selected buds have been sold to nurserymen and growers, the price being 5 cents per bud to members of the Fruit Growers Supply Co. and 6 cents to others. This business has been conducted as a public service to the citrus industry, and the results have been shown in improved yields as regards both

quantity and quality of fruit produced by the trees grown from the selected buds.

Where organizations of growers are not available through which the work of the selection and distribution of commercial citrus bud wood can be carried on, individual growers and propagators can make arrangements to conduct this work independently or through mutual agreements. However, experience has proved that, wherever possible, commercial bud selection and distribution work can be most efficiently carried out by the cooperation of associations, growers, and nurserymen. When properly organized it can be made self-supporting through the sale of buds, and of value to every interest concerned.

CARE OF BUD WOOD

Citrus bud wood should be used as soon as possible after it is cut from the select parent trees. If it is necessary to keep the bud wood for some time before it is used, it should be packed in moist, sterilized sphagnum moss and stored in a cool room having fairly uniform temperature and humidity. The ideal conditions for such a room are a temperature of about 60° F. and a relative humidity of 80 to 90 per cent. The moss used for packing the bud wood should be thoroughly moistened and sterilized with live steam for about an hour, after which it can be run through an ordinary clothes wringer in order to squeeze out all of the excess moisture. Under proper storage conditions citrus bud wood can be kept in good viable condition for several months.

BUDDING

The most favorable time for budding is generally during the spring months. However, budding can be done successfully at any time during the growing period of the trees. Budding in the late fall is sometimes preferable to summer budding, as the buds will remain dormant in the stocks until the following spring and will then make an early start into growth. Fall budding also allows nurserymen to spread their work more satisfactorily than to crowd it all into the spring period. High budding, that is, the insertion of the buds as high on the stocks as possible, is recommended for southwestern conditions.

In top-working undesirable trees, two or more of the main limbs should be selected as the foundation for the new head, as shown in Figure 11. The select buds should be inserted in these limbs, two or more in each, about 1 to 2 feet from the trunk of the tree. After the buds have made a union with the tree the limbs should be sawed off about 6 inches above the inserted buds. The freshly cut surfaces should be covered with grafting wax, pure lead paint, or some pruning compound, and the remainder of the tree should be covered heavily with whitewash, cloth, or other material so as to protect the trunk and limbs of the tree from sun scald or other injuries due to exposure. After about a year's growth the limbs should be cut back again so that only one bud is left on each. These second cuts should slope downward from a point directly above the bud union, and the surfaces should be again protected so they will heal completely. Top-worked trees should be inspected frequently for the

first two or three seasons and all growth removed except that from the select buds. In one or two years the growth from such buds will begin bearing fruits, and it should reach normal production in from three to five years, depending on the variety and the climatic and cultural conditions.

SUMMARY

Bud variation in citrus fruits is of more or less frequent occurrence and in many instances is of great economic importance to citrus growers.

The investigations that have been under way since 1909 indicate that undesirable bud variations can be largely eliminated from commercial citrus plantations by top-working such trees with bud wood from trees known to produce continuously uniform fruit of the character desired. The selection of these trees is most easily and satisfactorily made through the keeping of performance records.

Individual citrus-tree performance records are being kept by many citrus growers.

Records for an even number of successive normal seasons are desirable. For some purposes two seasons' records of full-bearing trees are probably sufficient; in other cases four or more seasons' records are preferable. The longer the period during which performance records are kept and the greater the number of trees recorded, the more valuable the records become.

These tree records enable the growers to locate good trees from which bud wood may be obtained, poor trees to be top-worked with select buds, and trees needing individual care. They also provide reliable data on which to base conclusions concerning the results of tree or orchard treatments.

Each tree in the orchard should be given a number, by means of which it can always be identified and easily found.

The work of weighing or estimating and recording the crops of the individual trees can be done with little extra expense by adding one laborer to each picking crew, or by the owner in small orchards. This cost is small when considered in connection with the value to the grower of the information obtained thereby and oftentimes is repaid through the sale of bud wood from the superior trees.

Only fruit wood obtained from superior parent trees that have been found to bear uniformly desirable fruits for a period of several normal seasons should be used in propagation. This bud wood may be used immediately after cutting, or it can be kept in moist, sterilized moss in a cool room for several months.

The spring period of tree growth is usually the best time for budding. The tender young growth from the buds in nurseries and top-worked trees should be protected from possible injuries by extreme temperatures, insect attacks, diseases, or other causes. Care should be taken to inspect this growth at frequent intervals and to train it by pruning so as to form strong and properly spaced framework branches.

The fall period of growth can be used successfully for budding in the Southwest and is particularly useful where early spring growth is desirable. The buds used in the fall are allowed to remain dormant until early spring, when they are forced into growth by cutting off

the nursery stocks or the limbs of older trees to be top-worked, just above the point where the buds were inserted. Smooth, sloping cuts are advisable, and the cuts should be protected with grafting wax or other suitable material applied as soon as possible after they have been made.

As a rule, transplanting bearing citrus trees should be done only after sufficient performance records have been obtained to indicate the individual trees that are worth the cost of this procedure.

The care of individual trees is rapidly growing to be an accepted and essential factor in systematic citrus-orchard management. This work can be most successfully and economically carried out with the use of individual tree-performance records.

The results of atmospheric and soil conditions and treatments, pruning and other orchard practices can be definitely measured by means of adequate individual-tree performance-record data from which reliable conclusions can be drawn.

Progeny tests of consistently high or continuously low-yielding citrus trees provide definite information as to whether these characteristics are inherent or are due to environmental influences. From the results of such tests the best trees can be selected from the superior progenies for propagation and the inferior trees can be top-worked or replanted.

In order to provide adequate supplies of select bud wood for propagation for the benefit of the citrus industry, the selection, obtaining, and distribution of such propagating material can best be handled through associations of growers. Where this plan is not feasible, the individual propagators can oftentimes make mutually satisfactory arrangements with growers to obtain select bud wood. The cost of obtaining the tree records as the basis for the selection of this bud wood has been returned in many instances under observation through the sale of selected buds.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

December 5, 1928

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26

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